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Title: Analysis of D3315-38A-X NOx sensors tested on March 16-17, 2017

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Analysis of D3315-38A-X NOx sensors tested on March 16-17, 2017

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March 20, 2017

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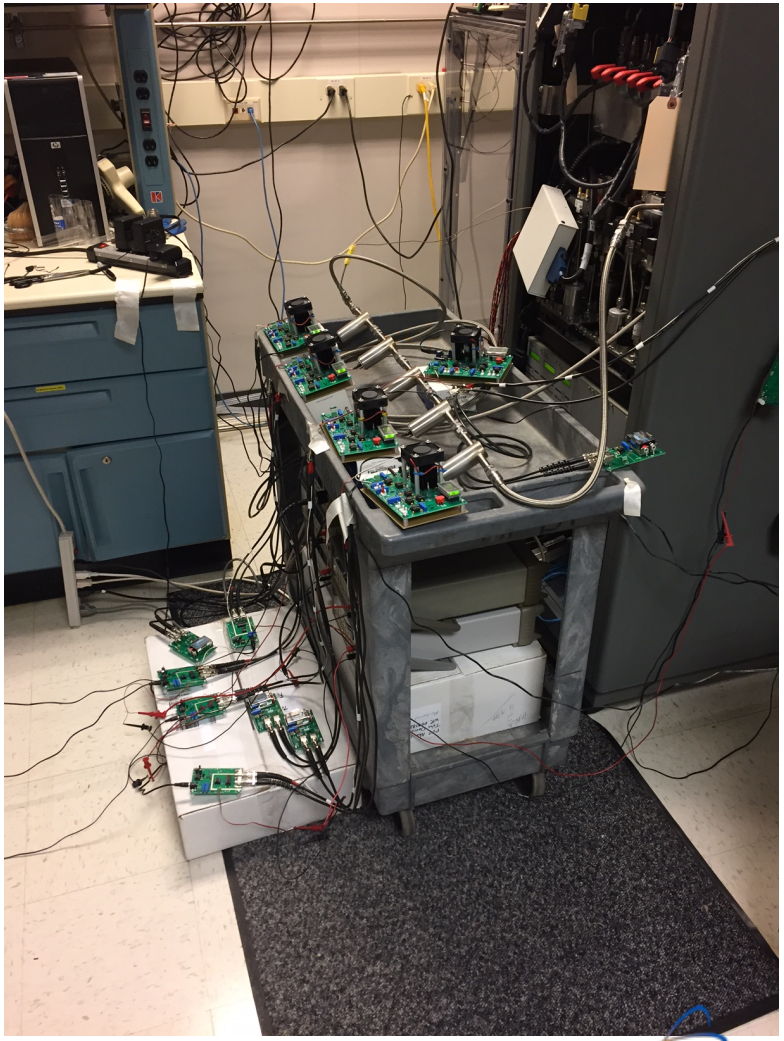
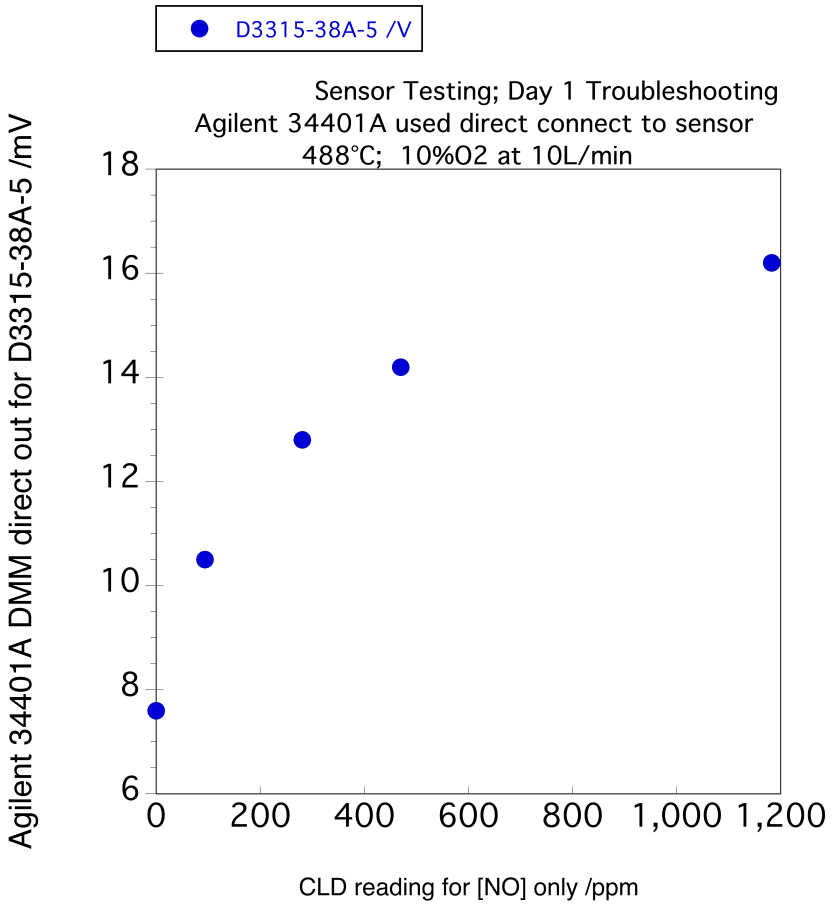
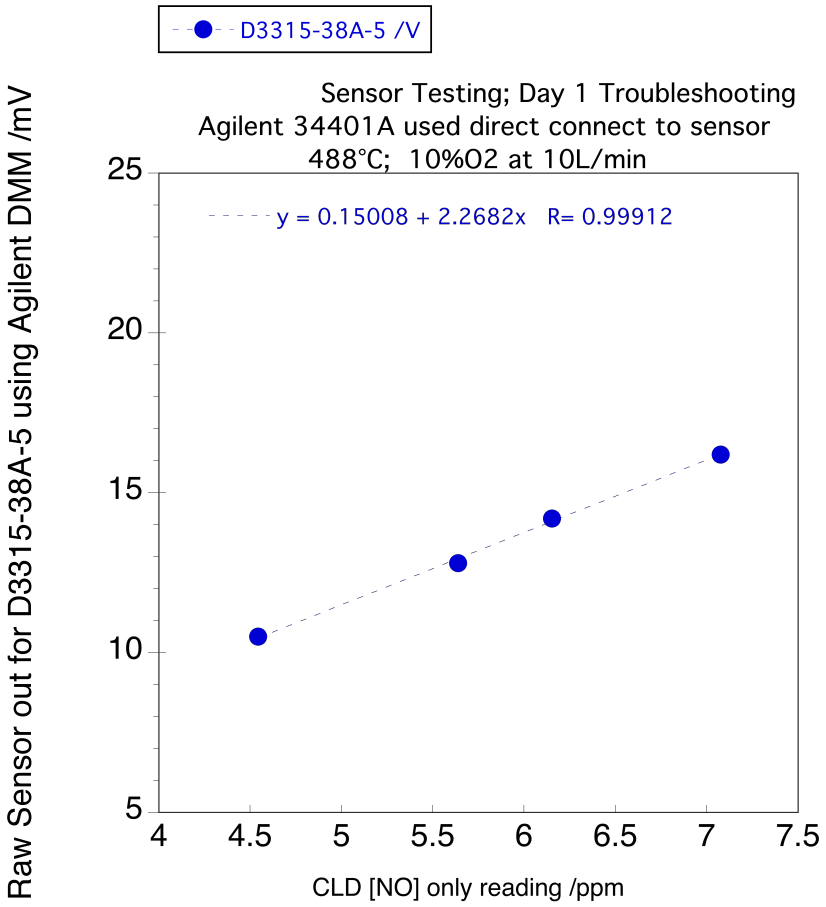
Initial Tests with NO only. D3315-38A-5 connected to Agilent 34401A DMM

- Sensors connected to HIBs and HIBs connected to DatAcq system at 100kOhm resistors showed no changes when various levels of NO were tested.
- HIBs were removed and an Agilent DMM (newer model than used at LANL) was located.
- Sensor attached to Aglient DMM behaved normally to NO.
- Only test gas available was NO.



D3315-38A-5, Initial NO results (488°C) connected directly to DMM. Sensor is unbiased and in this mode, will show small sensitivity to NO. Unbiased mode will yield highest sensitivity to HC's. Sensor appears normal behavior and does not show signs of saturation even at 1200 ppm (CLD) NO level.





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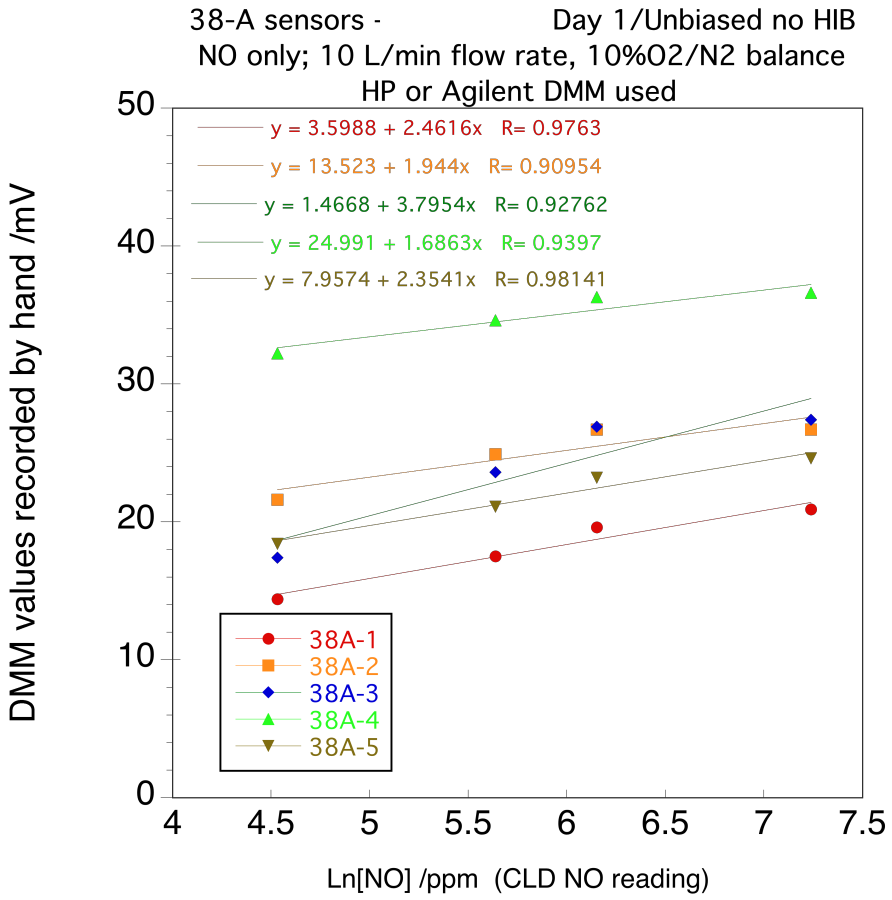
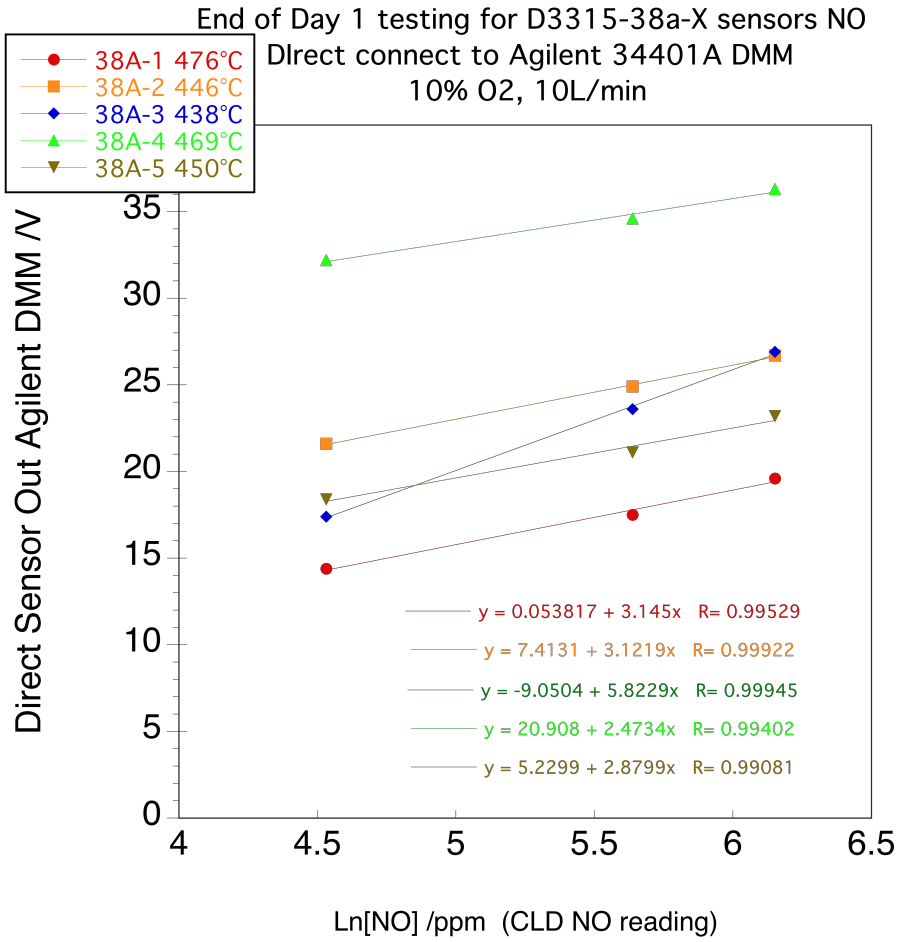
End of day 1, 5 DMMs located and HIB circuits removed. Sensor voltages recorded by hand. Sensor temperatures were left alone at values as shown. Higher [NO] show sensors saturated above 1200ppm in unbiased mode. 1394ppm data point was removed and data plotted in log-linear fashion.





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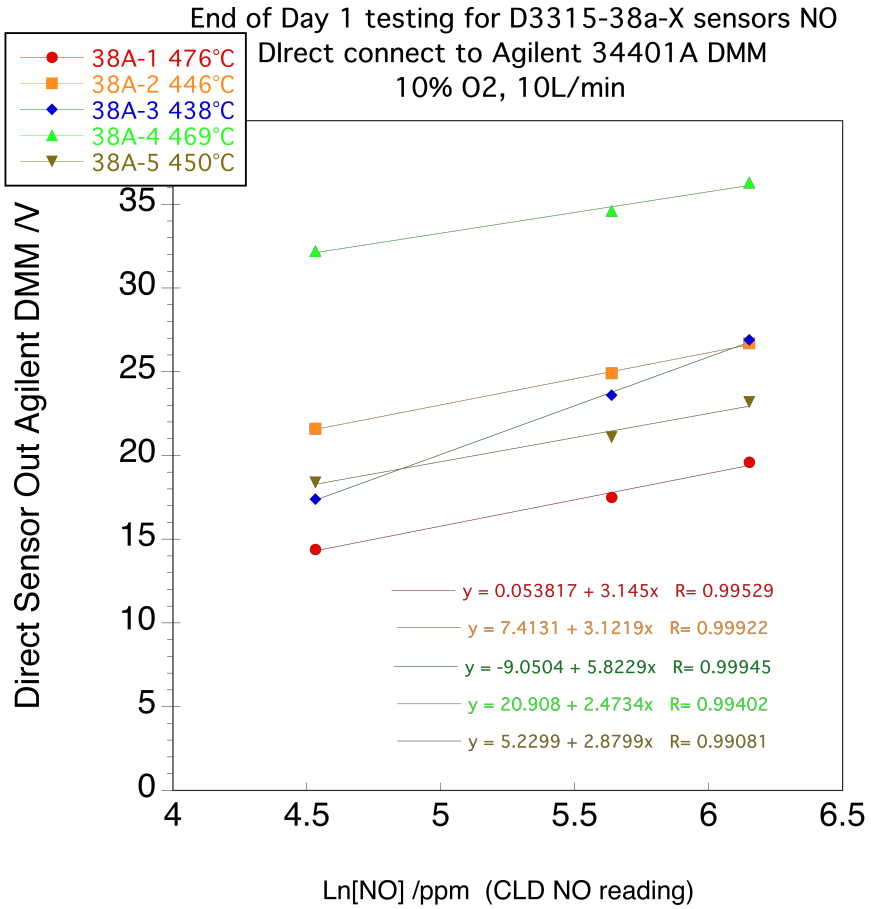
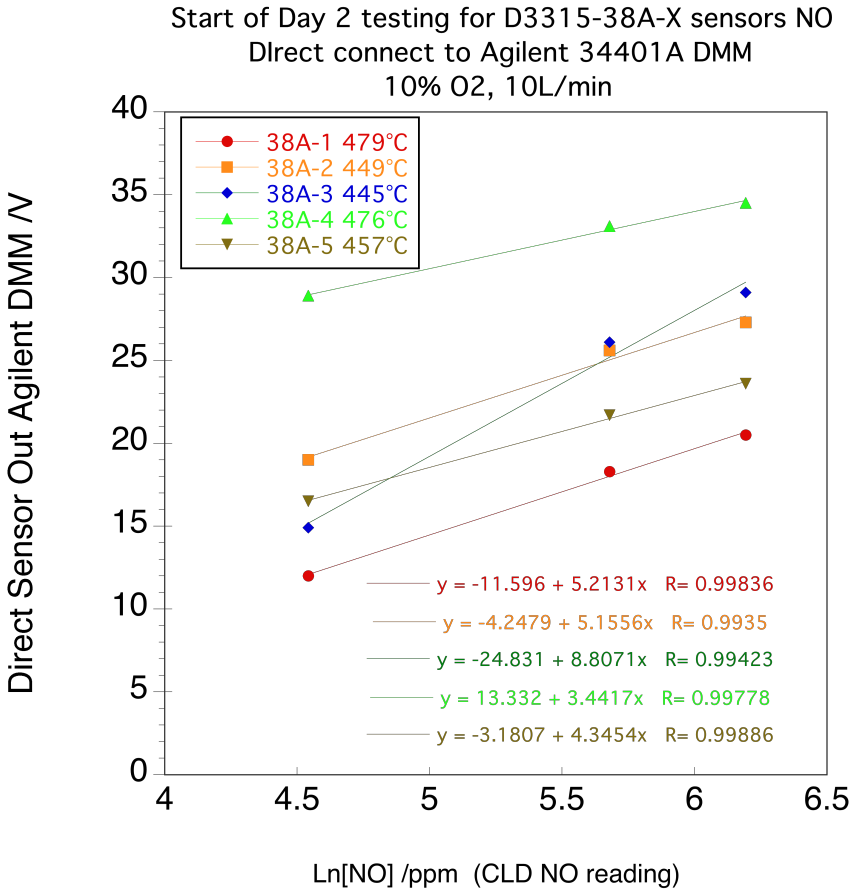
Next day, recorded sensor T data and repeated unbiased experiment.

Day 1



Day 2



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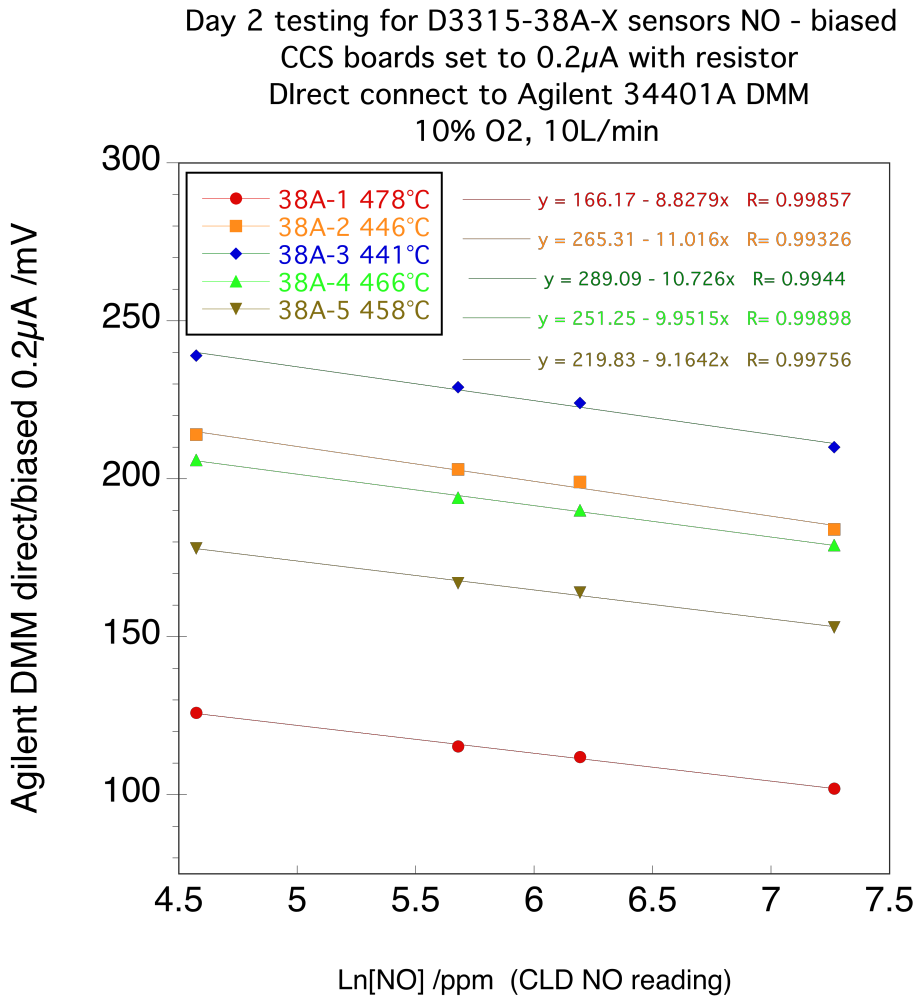
Bias experiments were next. Constant Current Source boards were all adjusted to 0.2µA current and connected to sensors with DMM's. Sensor temperatures were NOT readjusted to produce 200mV baseline. Note, sensors no longer saturate at 1390 ppm and sensitivity to NO has been augmented. These data show normal behavior.



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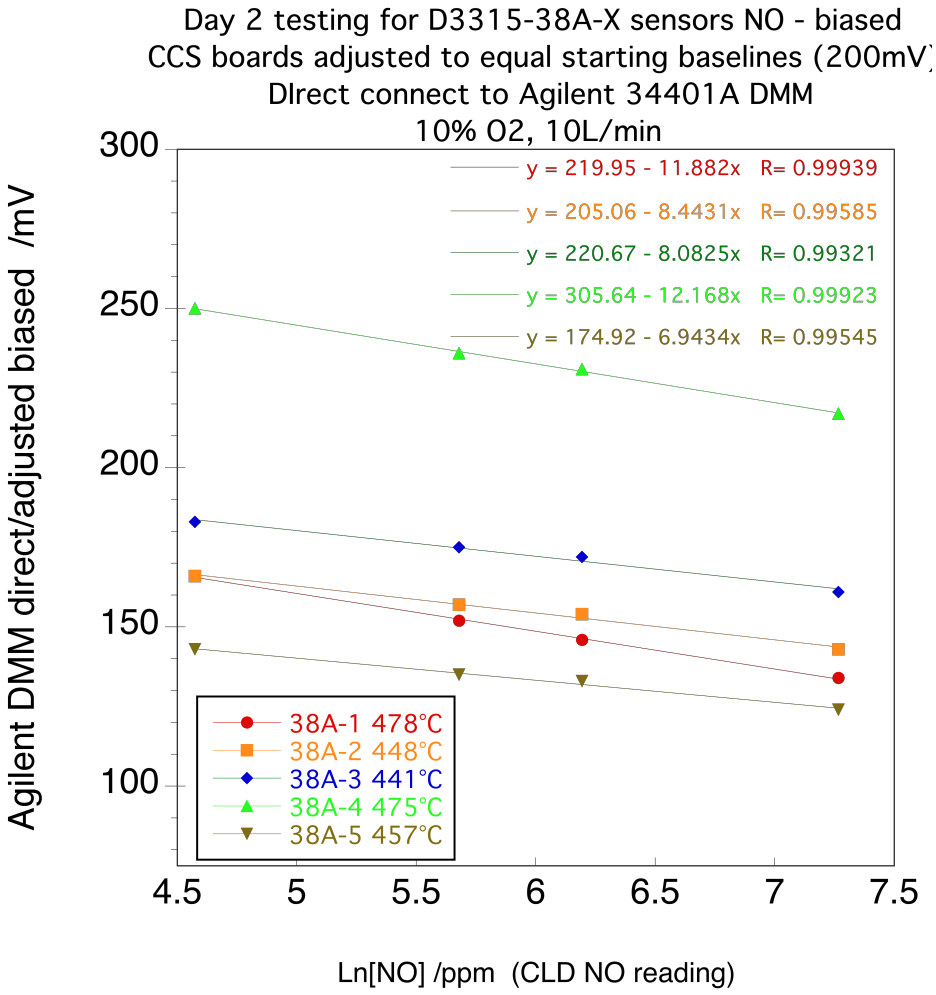
Bias current levels were adjusted so that each sensor would have a 0ppm baseline voltage of 200mV. These adjustments were made under static flow(?) and 10% PO2 conditions (?). However, when automated test run commenced, there was a large shift in 0ppm voltages. This should not have occurred unless environment (PO2/gas composition?) around sensor changed. Heater resistances (T) did not change much. Otherwise, sensor behavior appears nominal. Temperature and bias conditions differed for all sensors and different responses would be expected.



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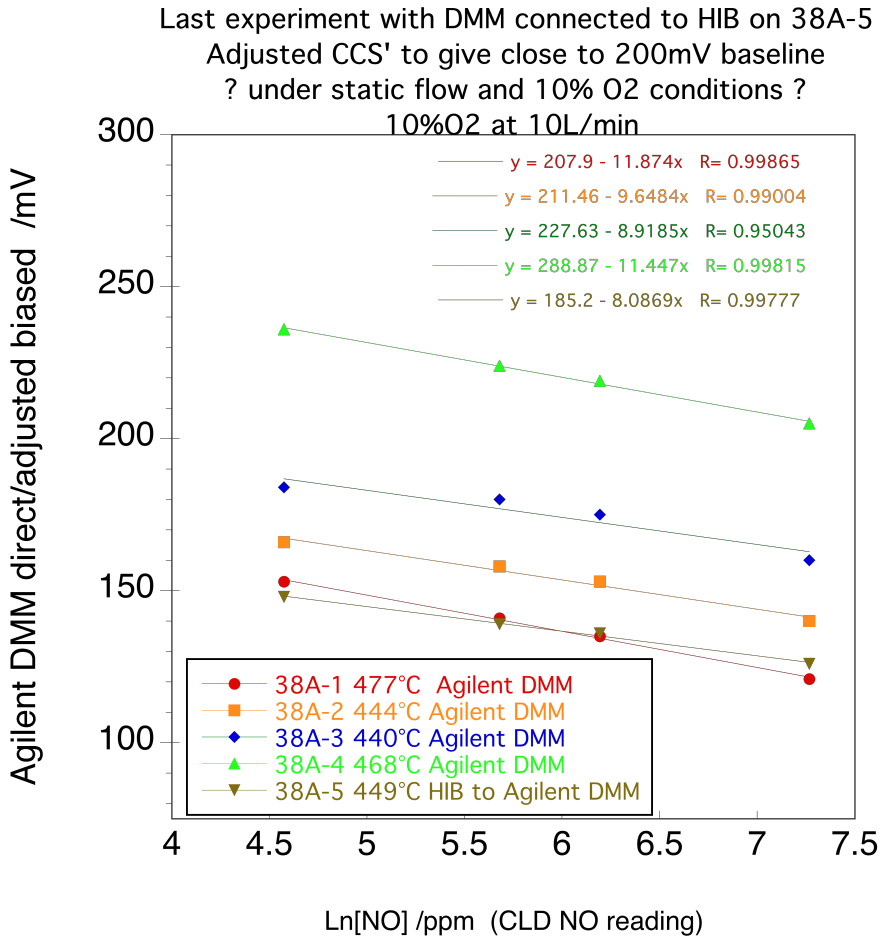
Final experiment: again attempt to equalize sensor baseline (0ppm NO) voltages to 200mV. See Excel spreadsheet for behavior of 0ppm NO voltages. The HIB was attached to sensor D3315-38A-5 and Agilent DMM used to measure HIB output by hand. HIB caused change in calibration of sensor 5 but did not change sensor characteristics. Agilent DMMs may be used to log from HIB boards or from sensors directly if baseline offset and gain are not required.



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Final thoughts on results of initial testing of LANL NOx sensors

- We did not have time to understand the automated sensor test system thoroughly. Observations made during testing suggest that there may be a N2 purge and we may not know actual flow rates at all times.
- Heater power could be seen adjusting to substantial flow rate changes during course of automated flow test operation.
- Large reversible jumps in sensor baseline observed during different stages of the automated test routine may suggest a large reduction in oxygen or even a N2 purge during automated test routine.
- Large shift in baseline voltages under bias are unusual and not seen during testing at LANL. We need to explain this.
- LANL recommend taking following steps: verify static flow conditions and at a fixed PO2 level during sensor T adjustment (i.e. tuning power supplies to desired current and voltage values); maintain PO2 throughout experiments at least during initial testing and calibration, and in particular, when adjusting sensor bias current.
- Some sensor anomalies conflicting with known trends in behavior were seen but they appear to be reproducible and linked to certain stages in the test routine.
- In order to improve measurements of sensor to sensor variability (if this is required or desired at this stage of testing), recommend using LANL approach to fix applied current bias at 0.2µA and adjust sensor T, using CRPS-H control units to, achieve equal sensor baseline ca. +200mV.